PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H04L 12/56

A1

(11) International Publication Number: WO 98/53577

(43) International Publication Date: 26 November 1998 (26.11.98)

(21) International Application Number: PCT/US97/08688

(22) International Filing Date: 22 May 1997 (22.05.97)

(71) Applicant: BELL COMMUNICATIONS RESEARCH, INC. [US/US]; 445 South Street, Morristown, NJ 07960-6438 (US).

(72) Inventor: CISNEROS, Arturo; 36 Rosalie Avenue, Lincroft, NJ 07738 (US).

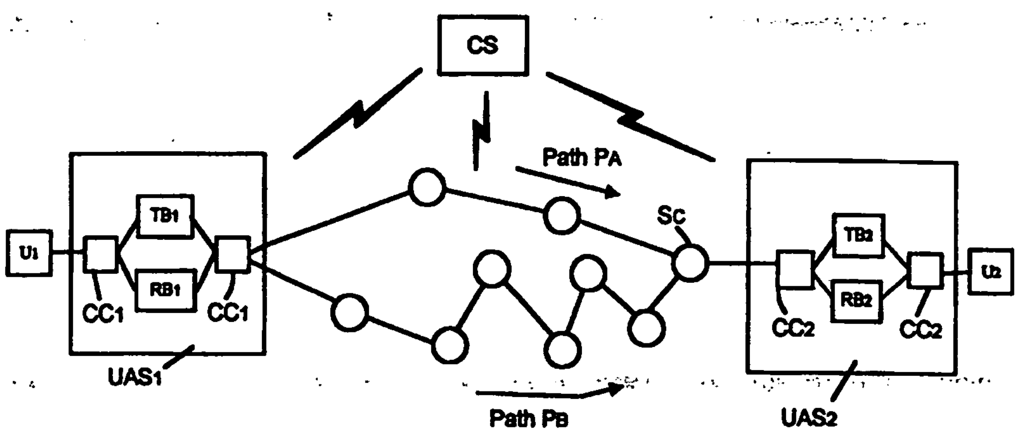
(74) Agents: GIORDANO, Joseph et al.; International Coordinator, Room 1G112R, 445 South Street, Morristown, NJ 07960-6438 (US).

(81) Designated States: CA, CN, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.

(54) Title: SYSTEM AND METHOD FOR EQUALIZING DELAY IN A DYNAMIC PACKET SWITCHING NETWORK



(57) Abstract

A system and method for equalizing delay in a dynamic packet switching network using transmit and receive buffers. The network includes a plurality of user access stations each equipped with a transmit buffer (TB1, TB2) and a receive buffer (RB1, RB2), and plurality of switches (Sc) and communication links interconnecting the user access stations (UAS1, UAS2). A control station (CC1) having communication links to the switches (Sc) and user access stations (UAS1) operates to set up and change transmission paths between the user access stations, and to control the buffers in the user access stations to equalize packet transmission delay through the network and to eliminate packet rate doubling upon changing transmission paths. The system also includes a buffer shifting feature whereby a controlled buffering in a transmitting user access station is gradually shifted to a buffer in a receiving user access station during a period of time following a change from a longer transmission path to a shorter transmission path.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

SYSTEM AND METHOD FOR EQUALIZING DELAY IN A DYNAMIC PACKET SWITCHING NETWORK

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to routing and transferring data and, in particular, to a system and method for equalizing delay in a dynamic packet switching network that routes and transfers data in addressed packets.

Description of the Related Art

Telecommunication networks exist that interconnect large numbers of user stations using telecommunication facilities. These networks utilize transmission systems, switching systems, and station equipment to transmit voice, video, and data between two points. The physical circuits between two points in the network are referred to as links, and the points of junction of the links are referred to as nodes. The user stations in data transmission networks may be telephones, terminals, printers, facsimile units, computers, and the like.

Packet switching networks were designed to provide a more efficient method of transferring data over networks. However, packet switching networks can also be used to transmit digitized voice. A network that uses packet

switching as a means of transmitting data is commonly referred to as a packet switching data network (PSDN).

A packet is a discrete unit of a data message that is routed individually over a PSDN. Each packet contains control information that enables the message to be reassembled in proper sequence before it reaches its final destination. Packet switching is efficient because packets occupy the channel or path through the network only for the brief time they are in transit, in contrast to a circuit-switched message, which requires the use of the transmission line for the duration of the message. On completion of the data transmission, the channel or path is made available for transfer of other packets. The transmission lines through the PSDN are supplemented with computerized switches that control traffic routing and flow. A standard feature of packet switching is automatic error detection and correction of transmitted packets.

A conventional communications network using data packet switching is shown diagrammatically in Fig. 1. Users and other networks access this network through user access stations ("UAS"), shown, for example, in Fig. 1 as UAS_1, UAS_2, and UAS_3. Other networks N_1, N_2 are considered to be like other users. User access stations send user data to the network and receive user data from the

network through one or more switches S_j. Paths are established through the network of switches S_j in order to set up virtual communication channels between users on different user access stations. The transmissions delay for a data packet to go from one UAS to another UAS depends on the particular path chosen.

A typical transmission delay time through the network will be referred to as T. For example, T could be 20 milliseconds. The longest path chosen for a virtual connection through the network in a typical case has a transmission delay of 10T. For example, for T = 20 milliseconds, 10T = 200 milliseconds.

Data packet size need not be constant. Data packet size can be fixed, as it is in ATM networks. However, it must be no longer than a maximum length. The maximum packet length is such that the latency time to transmit the packet over any of the links k_i or l_γ is smaller than T/10. The links k_i are those connecting the user access stations to the switches, and the links l_γ are those connecting switches to other switches.

Some packet switching data networks are dynamic in a number of ways, for example, a network of packet switches on satellites in non-earth synchronous orbits. The communication links k_i between the user access stations UAS and the switches S_j are not permanent. Links k_i are

alive for a typical period of time of about 15,000T (for example, 5 minutes for T = 20 milliseconds). When old links k_i are removed, new ones are established, but the new links k_i are almost always established on a new switch S_j. For example, when link k_2 (Fig. 1) is removed a new link between UAS_1 and S_2 may be established. There is always at least one link between a UAS and a network switch S_j.

The links l_y between switches S_j are not permanent; they have typical lifetimes of about 30,000T (for example, 10 minutes for T = 20 milliseconds). However, the pattern of links must satisfy certain conditions. There are always enough links to allow any UAS to communicate to any other UAS. Some of the links k_i or l_y may be permanent or much longer lived than stated above.

In a typical system, there are control stations CS having communication links to the network switches S_j. Their function is to control the network and to set up and tear down virtual connections. Any user access station UAS can always communicate with at least one control station CS. The location of the control stations CS are not germane to the present invention. It will be assumed that the network interconnection pattern (links k_i and l_y) is predictable and can be computed by the control stations CS for any future time. In practice, all that

is needed is the ability to compute the pattern into the future for the duration of the longest virtual connection established at the present time. Malfunctions can affect the predictability, but there exist ways of handling malfunctions.

A virtual connection between two network users that lasts longer than the link lifetimes must take different paths through the network during the connection lifetime. It will be assumed that the dynamic interconnection pattern (links k_i and l_y) is such that a series of paths can be chosen for the duration of the virtual connection, and each path can be used for at least a time period 1,200T (for example, 4 minutes for T = 20 milliseconds). This is, of course, as in any other kind of network, assuming bandwidth availability. If there is not enough bandwidth available, the connection cannot be set up. Resources are reserved for the expected duration of the call. As shown in Fig. 2a, for each of a series of consecutive time intervals t_1, t_2, t_3, . . . , t_n there are corresponding paths P_1, P_2, P_3, . . . P_n, such that path P_i is used during time interval t_i for the virtual connection.

Referring to Fig. 2b, a first path P_1, goes through switches S_1, S_3, S_4, S_5, S_9, S_{10}, S_{11}, and S_{13}, while a second path P_2 goes through switches S_2, S_6, S_7, S_{11}, and S_{13}. For

the same virtual connection between UAS_1 and UAS_2, path P_1 is used during time interval t_1, and path P_2 is used during time interval t_2, and so forth.

Problems are caused by the changes in paths through the network used by one virtual connection. As shown in Fig. 3, a virtual connection is set up between user U_1 on UAS_1 and user U_2 on UAS_2. During the first time interval t_1, path P_A is used. During the second time interval t_2, path P_B is used. Path P_A has a transmission delay time from UAS_1 to UAS_2 equal to t_a, while path P_B has a transmission delay time from UAS_1 to UAS_2 equal to t_b. It should be noted that the transmission delay times t_a and t_b are not intervals during which paths P_A and P_B are used, that is given by the intervals t_1 and t_2.

It will first be assumed that $t_a < t_b$ (for example, $t_a = 20$ milliseconds and $t_b = 100$ milliseconds), and that there is no buffering at UAS_2. After the end of time interval t_1, the virtual connection uses path P_B instead of path P_A. The first data packet traveling along path P_B will arrive at UAS_2 a period of time $t_b - t_a$ later than it would have if it had gone on path P_A. This will leave a silent gap of duration $t_b - t_a$ in the data stream (for example, $t_b - t_a = 80$ milliseconds) which is too large to be acceptable for many communication services. This

problem is simple to correct, however changing from a longer path P_B to a shorter path P_A causes more difficult problems, as explained below.

It will now be assumed that during the first time interval t_1, path P_B is used, and during the second time interval t_2, path P_A is used (see Figs. 4a and 4b). Again, t_a is the transmission delay along path P_A, and t_b is the transmission delay along path P_B, and $t_a < t_b$. There is no buffering at UAS_2 or at UAS_1.

Now assume that paths P_A and P_B have a common switch S_C, as shown in Fig. 4a. At the end of the time interval t_1, the connection will be changed from path P_B to path P_A. When a data packet first arrives at switch S_C along path P_A there are earlier data packets from the connection still traveling along path P_B (there is also an interpacket spacing time, but this is negligible for the problem described). There will be a period of time equal to $t_b - t_a$ during which switch S_C receives packets from the connection at twice the normal rate. If the link from switch S_C to UAS_2 is fully (or close to fully) utilized, switch S_C must buffer cells from this connection for a period much longer than $t_b - t_a$. If left uncorrected, this will cause delay and possibly increase cell loss probabilities for other virtual connections (cell = data packet).

If paths P_A and P_B do not have a common switch, as shown in Fig. 4b, UAS_2 must maintain two links for a time interval $t_b - t_a$, during which time it gets cells at twice the normal rate for the connection. This will also result in an increased delay and increased cell loss probabilities for other virtual connections.

SUMMARY OF THE INVENTION

It is thus an object of the present invention to provide an improved system and method for routing and transferring data in addressed data packets, which overcomes the above-described problems in dynamic packet switching networks.

It is a further object of the present invention to provide a system and method for equalizing delay in a dynamic packet switching data network and eliminating packet rate doubling upon changing transmission paths.

Additional objects, advantages and novel features of the invention will be set forth in the description that follows, and will become apparent to those skilled in the art upon reading this description or practicing the invention. The objects and advantages of the invention may be realized and attained by the appended claims.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as

embodied and broadly described herein, the apparatus of this invention comprises a system for equalizing delay in a dynamic packet switching network, comprising a buffer means for buffering a packet transmission through the network for equalizing packet transmission delay and for eliminating packet rate doubling upon changing transmission paths through the network.

It is preferred that the buffer means comprises a first buffer means for buffering a packet transmission at a receiving user access station for equalizing packet delay through the network upon changing from one transmission path to another transmission path. The buffer means also preferably comprises a second buffer means for buffering a packet transmission at a transmitting user access station for eliminating packet rate doubling when a change is made from a longer transmission path to a shorter transmission path through the network. A means for controlling the second buffer means provides a first amount of buffering at the transmitting user access station immediately upon changing from a longer transmission path to a shorter transmission path through the network, and means for gradually shifting the first amount of buffering from the second buffer means to the first buffer means during a

period of time following the change from a longer transmission path to a shorter transmission path.

In a further aspect of the present invention, in accordance with its objects and purposes, the apparatus hereof comprises a dynamic packet switching network, comprising first and second user access stations each having at least one buffer to delay packet transmission, and a network of switches and communication links interconnecting the first and second user access stations. A control station having communication links to the switches and user access stations provides means for setting up and changing transmission paths between the first and second user access stations, and means for controlling the buffers in the first and second user access stations for equalizing packet transmission delay through the network for different transmission paths.

It is also preferred that the control station have means for controlling the buffers in the first and second user access stations for eliminating packet rate doubling when a change is made from a longer transmission path to a shorter transmission path through the network. The means for controlling the buffers in the first and second user access stations comprises means for causing the buffer in the second user access station to delay packets received from the first user access station for a

sufficient time to cause a total transmission delay time for each transmission path equal to a transmission delay time of a longest one of the transmission paths.

It is also preferred that the means for controlling the buffers in the first and second user access stations comprises means for causing the buffer in the first user access station to delay packets transmitted from the first user access station to the second user access station for eliminating packet rate doubling when a change is made from a longer transmission path to a shorter transmission path. The means for controlling the buffers also preferably comprises means for gradually shifting the buffering provided by the buffer in the first user access station to the buffer in the second user access station during a period of time following a change from the longer transmission path to the shorter transmission path.

In a further aspect of the present invention, in accordance with its objects and purposes, the method hereof comprises a method for equalizing delay in a dynamic packet network, comprising the steps of providing first and second user access stations each having at least one buffer to delay packet transmission, and a network of switches and communication links interconnecting the first and second user access

stations, setting up and changing transmission paths between the first and second user access stations across the network of switches and communication links, and controlling the buffers in the first and second user access stations to equalize packet transmission delay through the network for all of the transmission paths.

It is also preferred that the method comprise the step of controlling the buffers in the first and second user access stations to eliminate packet rate doubling when a change is made from a longer transmission path to a shorter transmission path through the network. The method also includes the step of gradually shifting a buffering from the buffer in the first user access station to the buffer in the second user access station after changing from a first longer path through the network to a second shorter path through the network.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more clearly appreciated as the disclosure of the present invention is made with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram providing a general overview of a conventional dynamic packet switching data network.

Fig. 2a illustrates an allocation of resources for a series of consecutive time intervals for a conventional dynamic packet switching data network.

Fig. 2b is a schematic diagram depicting the paths used during two intervals (for example) in a conventional virtual connection.

Fig. 3 is a schematic diagram showing a virtual connection that uses different paths between two users of a conventional dynamic packet switching data network.

Fig. 4a is a schematic diagram showing two paths with a common switch used in a virtual connection between two users of a conventional dynamic packet switching data network.

Fig. 4b is a schematic diagram showing two paths with separate links into a receiving user access station of a conventional dynamic packet switching data network.

Fig. 5a is a schematic diagram of a preferred embodiment of the present invention in which a buffer system is used at each user access station to equalize delay in the network.

Fig. 5b is a schematic diagram of the present invention showing two paths with separate links into a receiving user access station.

Fig. 5c is a schematic diagram of the present invention showing the delay equalizing system of the

present invention used to equalize delay across three transmission paths.

Figs. 6a and 6b are flow charts of the process steps used by the present invention to equalize delay in a dynamic packet switching data network.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to a preferred embodiment of the invention, an example of which is illustrated in the accompanying drawings.

Referring to Figs. 5a, 5b, 6a, and 6b, a system and method for equalizing data packet delay through a dynamic packet switching data network will be described. The system according to the present invention will also eliminate data packet rate doubling at a common switch along two paths used by one connection or data packet rate doubling at the receiving UAS.

As shown in Figs. 5a and 5b, two buffers are used at each user access station UAS. A receive buffer RB_n operates to delay packets so that delay is equalized to that of the longest paths used by the virtual connection. A transmit buffer TB_n operates to eliminate data packet rate doubling when a change is made from one path to another shorter path. A control station CS having communication links to the network switches S_j and the

user access stations UAS functions to control the buffers and the virtual connections of the network. The communication feeds to and from the buffers TB_n and RB_n are combined at cross connect elements CC_n in each of the user access stations. The details of the buffers and their operation in the packet network are described below.

The change of a virtual connection from a path P_A to a longer path P_B will be described first. The paths can have a common switch S_C before the receiving user access station UAS_2 (Fig. 5a), or the paths can enter the receiving user access station UAS_2 through two links without a common switch (Fig. 5b). The connection starts, for example, using path P_A. Packets traveling along path P_A undergo a transmission delay time t_a from UAS_1 to UAS_2. When the virtual connection is moved from path P_A to path P_B, the packets traveling along path P_B undergo a transmission delay time t_b from UAS_1 to UAS_2.

In order to equalize the transmission delay times for paths P_A and P_B, packets traveling along path P_A are delayed for a time $t_b - t_a$ in buffer RB_2. On the other hand, packets traveling along path P_B are not delayed at RB_2. After moving the virtual connection from path P_A to path P_B, the first packet for the connection traveling along path P_B arrives at RB_2 after the last packet

traveling along path P_A leaves the buffer RB_2. There is no gap in the data packet stream, and transmission delay time is the same from U_1 to U_2 when paths P_A or P_B are used.

The change of a virtual connection from path P_B to a shorter path P_A will be described next. During the time the connection is using path P_B, the transmission delay is t_b, and the packets are not delayed at either TB_1 or at RB_2. When the change is made to the shorter path P_A, the present invention avoids packet rate doubling by delaying packets for transmission along path P_A for a time $t_b - t_a$ in buffer TB_1. In this way, the first packet traveling along path P_A will arrive at S_C (Fig. 5a) or at UAS_2 (Fig. 5b) after the last packet traveling along path P_B arrived at S_C or at UAS_2. This eliminates data packet rate doubling and equalizes the transmission delay times for paths P_A and P_B.

Referring to Fig. 5c, the present invention will next be described for the case where a change to a new path P_C longer than P_A is made. Assume the connection uses paths P_B, P_A, and P_C (in that order) with transmission delays t_b, t_a, and t_c respectively. Also assume, as above, that $t_a < t_b$ and that $t_a < t_c < t_b$. Path P_B is the path with longest delay of the three paths. When the change is made from path P_B to the shorter path

P_A the procedure described above is used. As described, the packets are buffered and delayed for a time $t_b - t_a$ in the transmit buffer TB_1, but not in the receive buffer RB_2. If the system simply waits until the change is made from path P_A to path P_C, there will be a gap of time $t_c - t_a$ in the packet stream, and the total delay will be $(t_b - t_a) + t_c$, which is larger than t_b because $t_c - t_a$ is positive.

The problem just described is avoided by shifting the buffering of packets for the virtual connection from TB_1 to RB_1 during the time that the path P_A is being used. In one example of the present invention, it will be assumed that each path can be used for a time period of at least 12,000T (e.g., 4 minutes for T = 20 milliseconds), where T is the typical transmission delay through the network. It will also be assumed that there is a maximum transmission delay of 10T (e.g., 200 milliseconds for T = 20 milliseconds) for transmission across the longest path P_B.

The buffering delays applied in order to equalize the total delay are equal to the transmission time differences along two paths. Buffering delays are therefore also bounded by a maximum time equal to 10T. The average number of packets transmitted for the connection in a time 12,000T (path P_A minimum active

time) is 1,200 times larger than the average number of packets transmitted in a time 10T (maximum buffering delay). So the number of packets buffered at TB_1 is 1/1,200 times the number of packets the virtual connection delivers during the time period 12,000T, which is a lower bound to the period of time any one path is used, in particular, path P_A.

Buffering can be shifted from buffer TB_1 to RB_2 by sending packets from TB_1 to RB_2 at a rate one per thousand larger than the average for the connection. This procedure will take time $1,000(t_c - t_a)$ which is smaller than 10,000T and also smaller than the time path P_A is used. During this time packets are delayed at RB_2 for a time sufficient to make the total delay equal to t_b. At the start of the procedure packets are delayed by $t_b - t_a$ at TB_1 and by zero at RB_2. At the end of the procedure packets are delayed by zero at TB_1 and by $t_b - t_a$ at RB_2.

During the time period $1,000(t_b - t_a)$ the delay in buffer TB_1 changes linearly from $t_b - t_a$ to zero, and in buffer RB_2 the delay changes linearly from zero to $t_b - t_a$. At the end of this buffering shift, there is no delay at buffer TB_1, and a delay of $t_b - t_a$ at RB_2 thus occurs near the end of the use of the path P_A. When the change is made to the path P_C, the transmission delay is t_c, which

is longer than t_a. There will now be no gap in the packet stream out of UAS_2 to user U_2. The first packet traveling along path P_C will arrive at the buffer RB_2 a time $t_c - t_a$ later than if it had gone along P_A. During this time the connection to U_2 is fed from the buffer RB_2. The delay at buffer RB_2 will be $t_b - t_c$ for packets traveling along path P_C. The total transmission delay including buffering is equal to t_b, as mentioned above.

In order to accomplish the above delay equalizing procedure it is necessary to reserve 1/1,000 (0.1%) of the bandwidth in the network for buffer shifting.

Buffers TB_2 and RB_1 are used in an analogous way to equalize delay and eliminate gaps in the packet stream for the connection in the opposite direction. The requirement that a path must be used for at least a time 12,000T need not apply to the last path used by the connection.

Referring to Figs. 6a and 6b, the method for equalizing delay in a dynamic packet network according to the present invention will be further described as a series of process steps.

In Fig. 6a, the process steps for an initial start of the delay equalizing process are shown. The process starts by determining the path P_{max} that will be used having the maximum time delay t_{max} (e.g., P_B and t_b in the

example above). If the duration of the data transmission is indeterminate, the system will use the upper bound for t_{max}. A first path P_s having a transmission delay t_s is then set by the control system. If $t_s < t_{max}$, the system will delay packets by $t_{max} - t_s$ in RB_2 with no delay at TB_1. If $t_s = t_{max}$, the system will not delay the packets at either TB_1 or at RB_2.

In Fig. 6b, the process steps for equalizing delay in the network upon switching paths are shown. When the time comes for a path change to be made, the buffering, if any, is at RB_2. The current path is P_C with transmission delay t_c, and the new path is P_N with transmission delay t_n. If $t_n = t_c$, no buffering or delay changes are made by the control system. However, if $t_n > t_c$, a buffering delay of length $t_{max} - t_n$ will be applied at RB_2 to packets traveling along path P_N. The buffering delay was $t_{max} - t_c$ before the change and will be $t_{max} - t_n$ after the change. If $t_n < t_c$, the control system will apply a buffering delay of length $t_c - t_n$ in the buffer TB_1. The system will then gradually shift the buffering from TB_1 to RB_2 using the procedure described above during the time path P_N is used. At the end of the buffer shifting procedure all buffering delay will be at RB_2 and will be equal to $t_{max} - t_n$. The total transmission delay is always t_{max}.

The loop terminates during the use of the last path. If the process is in the middle of a buffer shifting procedure, there is no difficulty. The remaining packets in the network are delivered to U_2 with a constant delay equal to t_{max}.

The minimum length of time that any path (except the last) can be used can be reduced as desired. For example, if the minimum time a path must be usable is 1,200T (instead of 12,000T) then the buffering must be shifted from TB_1 to RB_2, when necessary, 10 times as fast. This implies sending one more packet per one hundred packets during the buffering shift process. This requires 1% of available bandwidth to be reserved for this purpose. This can be carried further if more bandwidth is made available for shifting.

It will be appreciated that the present invention is not limited to the exact construction or process steps that have been described above and illustrated in the accompanying drawings, and that various modifications and changes can be made without departing from the scope thereof. It is intended that the scope of the invention only be limited by the appended claims.

WHAT IS CLAIMED IS:

1. A system for equalizing delay in a dynamic packet switching network, comprising:

buffer means for buffering a packet transmission through the network for equalizing packet transmission delay through the network and for eliminating packet rate doubling upon changing transmission paths through the network.

2. The system according to claim 1, wherein said buffer means comprises a first buffer means for buffering a packet transmission at a receiving user access station for equalizing packet delay through the network upon changing from one transmission path to another transmission path.

3. The system according to claim 2, wherein said buffer means further comprises a second buffer means for buffering a packet transmission at a transmitting user access station for eliminating packet rate doubling when a change is made from a longer transmission path to a shorter transmission path through the network.

4. The system according to claim 3, further comprising means for controlling said second buffer means

to provide a first amount of buffering at the transmitting user access station immediately upon changing from a longer transmission path to a shorter transmission path through the network, and means for gradually shifting said first amount of buffering from said second buffer means to said first buffer means during a first period of time following the change from a longer transmission path to a shorter transmission path.

5. The system according to claim 4, wherein said shorter transmission path is used for a second period of time, and said first period of time is shorter than said second period of time.

6. The system according to claim 3, wherein a first longer path P_B through the network has a transmission delay t_b, a second shorter path P_A through the network has a transmission delay t_a, said transmission delay t_b being greater than said transmission delay t_a, and further comprising means for controlling said second buffer means to provide an amount of buffering at the transmitting user access station sufficient to cause a packet transmission delay equal to the difference between t_b and t_a immediately upon a change being made from said first longer path P_B to said second shorter path P_A.

7. The system according to claim 6, further comprising means for shifting the buffering provided by the second buffer means to the first buffer means during a first period of time following the change from said first longer path P_B to said second shorter path P_A, whereby at the end of the first period of time said first buffer means provides an amount of buffering at the receiving user access station sufficient to cause a packet transmission delay equal to the difference between t_b and t_a, and said second buffer means provides no buffering at the transmitting user access station.

8. The system according to claim 7, wherein said first period of time is shorter than a total time that the second path P_A is to be used.

9. The system according to claim 7, wherein said shifting means provides a gradual shifting of the buffering provided by the second buffer means to the first buffer means during said first period of time.

10. A dynamic packet switching network, comprising:

a first user access station having at least one buffer to delay packet transmission;

a second user access station having at least one buffer to delay packet transmission;

a network of switches and communication links interconnecting the first and second user access stations; and

at least one control station having communication links to the switches and user access stations, said control station having means for setting up and changing transmission paths between the first and second user access stations, and means for controlling the buffers in the first and second user access stations for equalizing packet transmission delay through the network for different transmission paths.

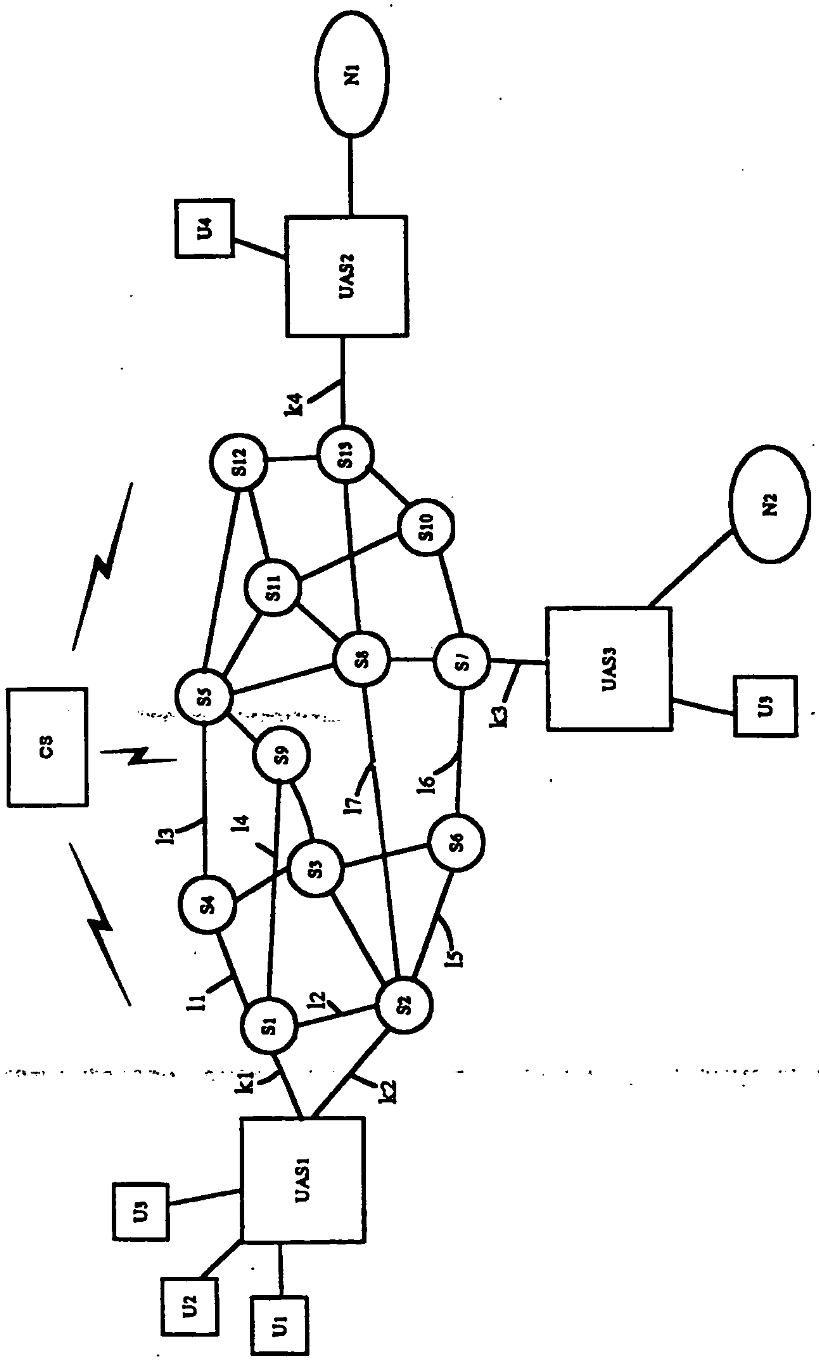


FIG. 1
(Prior Art)

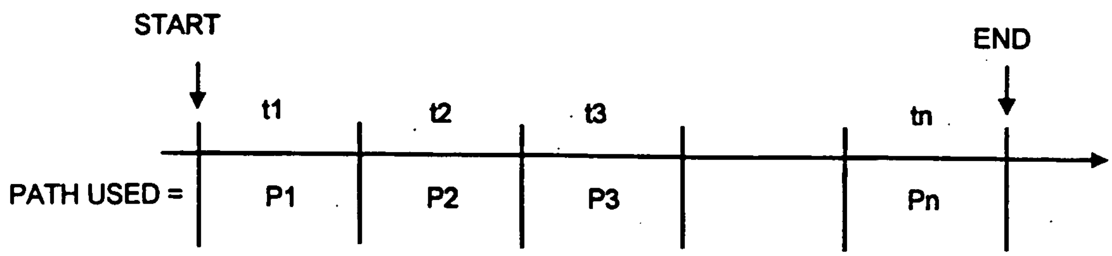


FIG. 2a
(Prior Art)

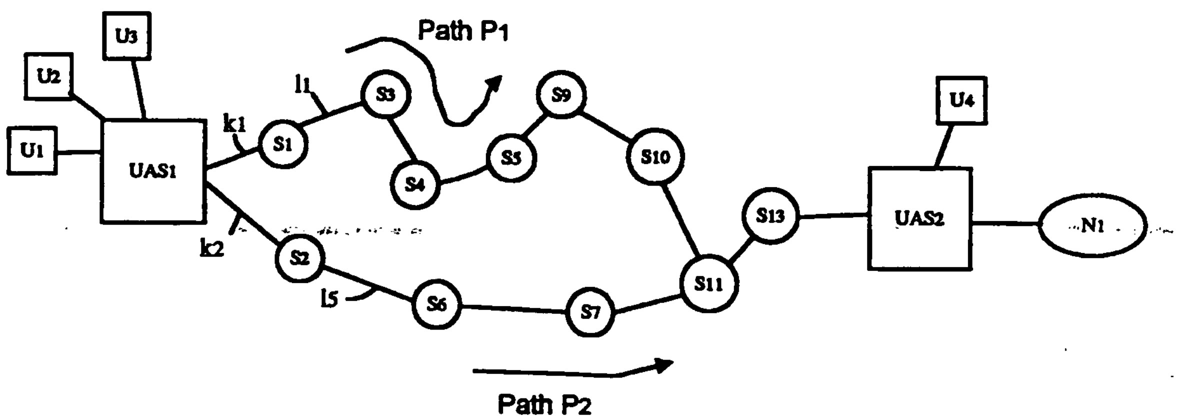


FIG. 2b
(Prior Art)

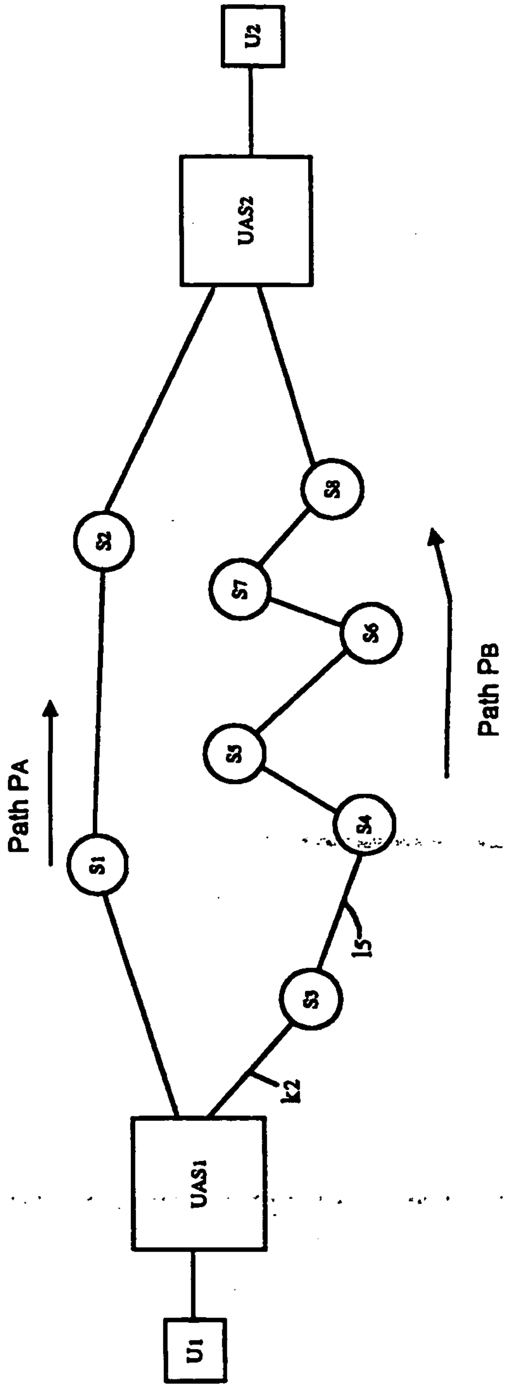


FIG. 3
(Prior Art)

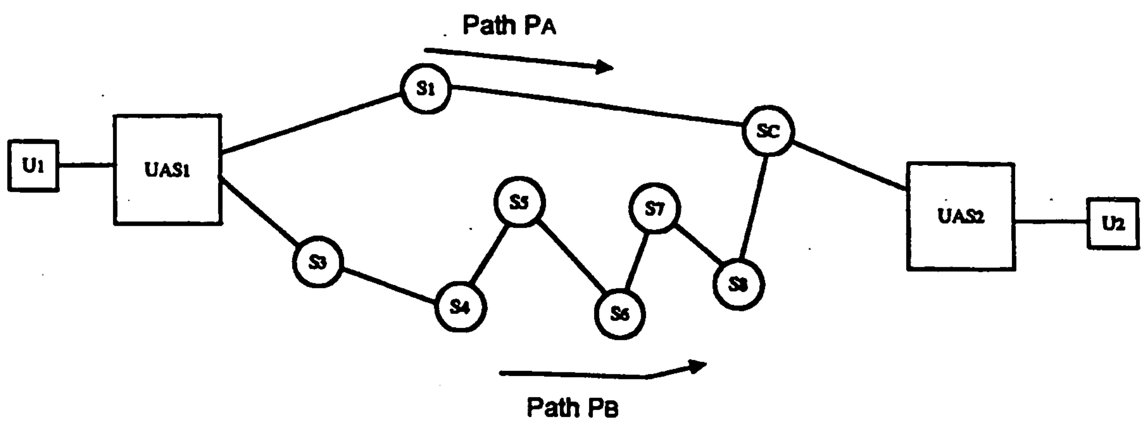


FIG. 4a
(Prior Art)

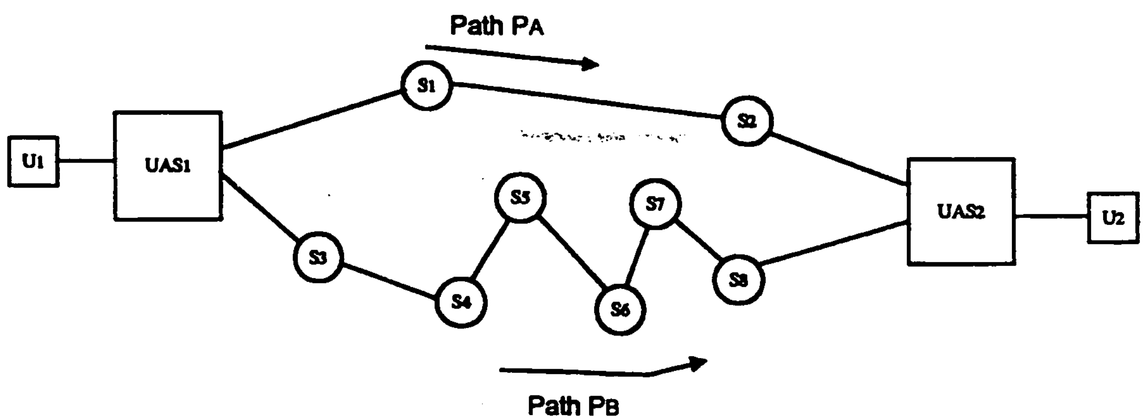


FIG. 4b
(Prior Art)

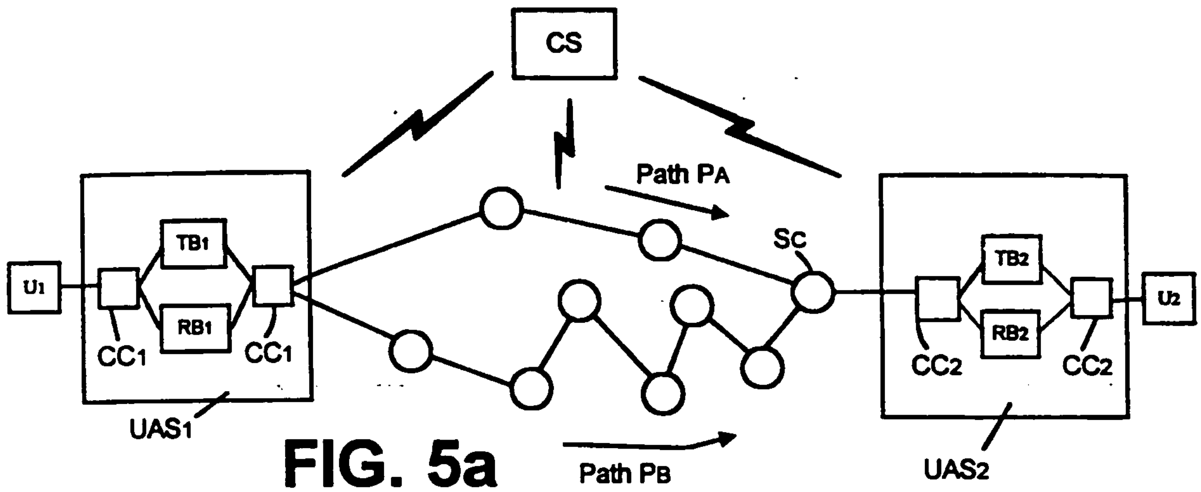


FIG. 5a

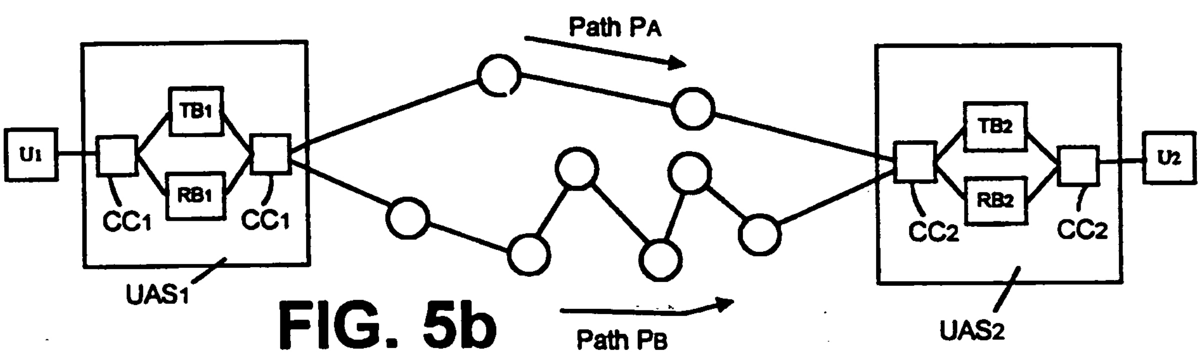


FIG. 5b

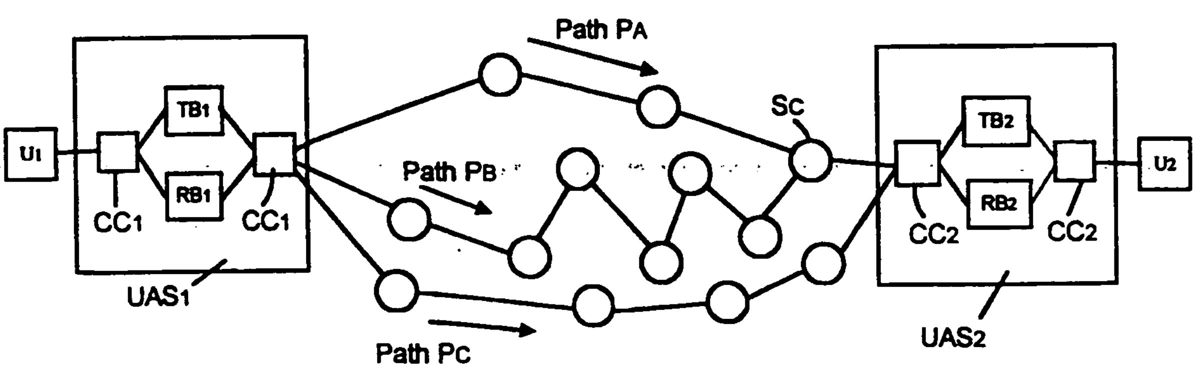


FIG. 5c

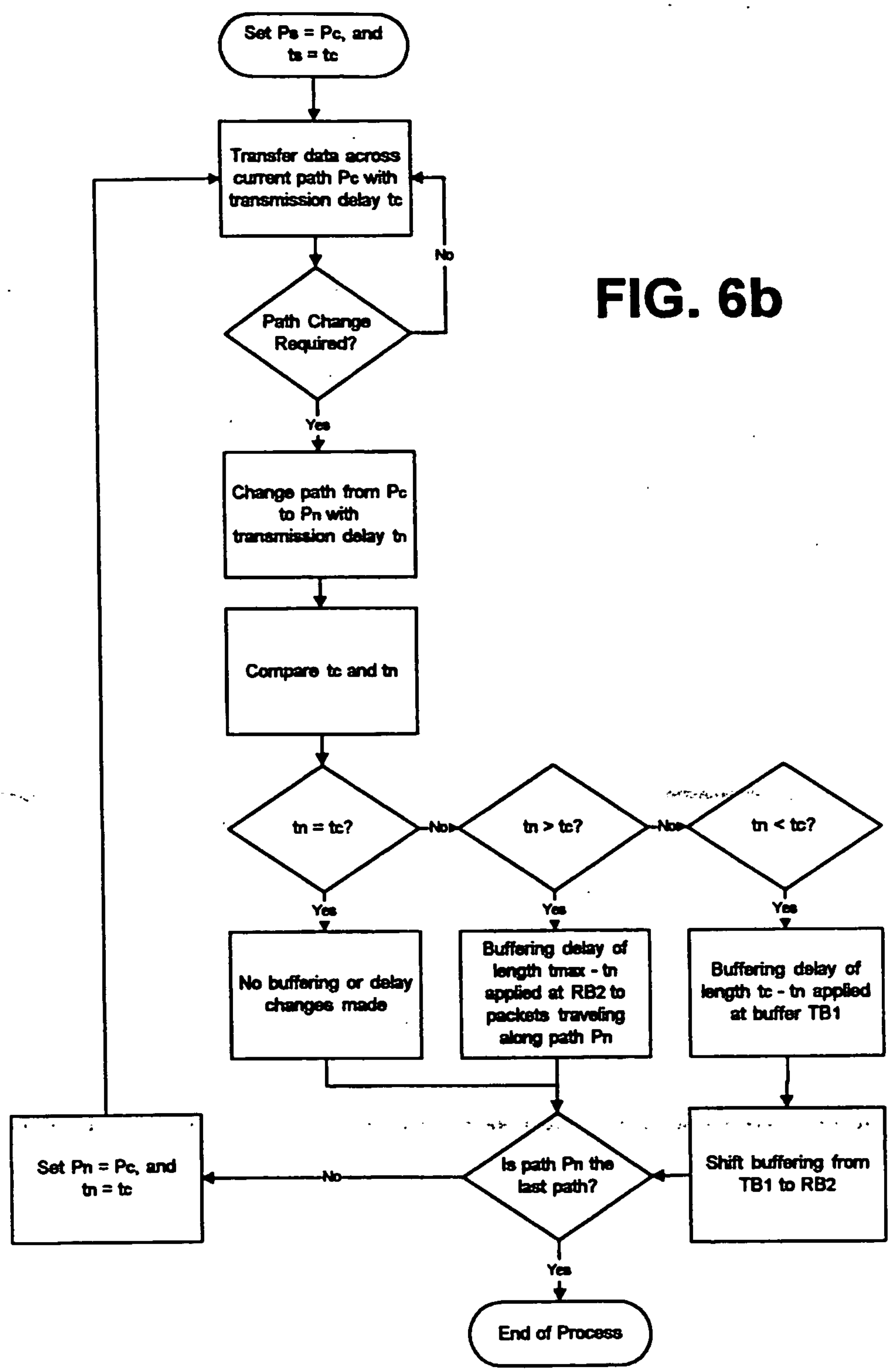

Set Ps = Pc, and ts = tc
Transfer data across current path Pc with transmission delay tc
No
Path Change Required?
Yes
Change path from Pc to Pn with transmission delay tn
Compare tc and tn
tn = tc?
No
tn > tc?
No
tn < tc?
Yes
Yes
Yes
No buffering or delay changes made
Buffering delay of length tmax - tn applied at RB2 to packets traveling along path Pn
Buffering delay of length tc - tn applied at buffer TB1
Shift buffering from TB1 to RB2
Is path Pn the last path?
No
Set Pn = Pc, and tn = tc
Yes
End of Process

FIG. 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/08688

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04L 12/56
US CL :370/ 394, 412
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/229, 230, 231,389, 394, 412, 419, 422, 426, 428, 429, 468, 473

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms: transmission delay, buffer?, queuing, sequencing, synchronization

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,817,085 A (DE PRYCKER) 28 MARCH 1989	1-10
A	US 5,193,151 A (JAIN) 09 MARCH 1993	1-10
A	US 5,381,404 A (SUGANO et al) 10 JANUARY 1995	1-10
X	US 5,381,408 A (BRENT et al) 10 JANUARY 1995, col. 2, lines 56-68.	1-2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 AUGUST 1997	16 SEP 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	SOON-DONG HYUN
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4700